The Forest Service of the U.S. Department of Agriculture

...Conducts forest and range research at more than 75 locations from Puerto Rico to Alaska and Hawaii.

...Participates with all State forestry agencies in cooperative programs to protect and improve the Nation's 395 million acres of State, local, and private forest lands.

...Manages and protects the 187-million-acre National Forest System for sustained yield of its many products and services.

The Pacific Southwest Forest and Range Experiment Station

...Represents the research branch of the Forest Service in California, Hawaii, and the western Pacific.

United States
Department of
Agriculture

Forest Service

Pacific Southwest
Forest and Range
Experiment Station

P.O. Box 245
Berkeley
California 94701

Research Note
PSW-348

December 1980

Physical Characteristics of Selected Fine Fuels in Hawaii—some refinements on surface area-to-volume calculations

Francis M. Fujioka David M. Fujii

Fujioka, Francis M., and David M. Fujii. 1980. *Physical characteristics of selected fine fuels in Hawaii—some refinements on surface area-to-volume calculations.* Res. Note PSW-348, 7 p., illus. Pacific Southwest Forest and Range Exp. Stn., Forest Serv., U.S. Dep. Agric., Berkeley, Calif.

Favorable growing conditions for fine fuels in Hawaii sustain an environment prone to conflagrations. In 1973, the State of Hawaii began use of Fuel Model A of the 1972 National Fire-Danger Rating System to diagnose fire potential. Soon after, a study was begun of the physical characteristics of three major fine fuels: *Andropogon virginicus* (broomsedge), *Melinis minutiflora* (molasses grass), and *Pennisetum setaceum* (fountaingrass). Surface area-to-volume ratios were estimated with the reciprocal harmonic mean. An approximation of the complete elliptic integral of the second kind was used as an additional refinement to surface area-to-volume ratio estimates of stalks with elliptical cross-sections. Bed depths and fuel loadings were estimated, also. Loading estimates were apportioned into live and dead categories on the basis of observed proportions-by-weight of each class. Surface area-to-volume, loading, and fuel depth estimates were generally higher than the corresponding parameters of standard grass models.

Retrieval Terms: Hawaii fine fuels, surface area-to-volume ratio, fire-danger rating, harmonic mean

Favorable growing conditions for fuels aggravate the problem of wildfire in Hawaii. A forest ravaged by fire soon gives way to grasses that threaten to hasten the spread of the next wildfire. Examples of this cycle are found throughout the State—at Makua and Helemano on the island of Oahu, Puna on the island of Hawaii, Puu Ka Pele on Kauai, Kahikinui on Maui, and Kaunakakai on Molokai.

To diagnose the day-to-day fire potential on conservation land, the Hawaii Division of Forestry began using Fuel Model A of the National Fire-Danger Rating System, in 1973, on a limited scale.[1] The Division subsequently phased into the AFFIRMS computerized system for processing data to estimate fire danger.[2] In the meantime, we started a study of the physical characteristics of three major fine fuels in Hawaii: broomsedge

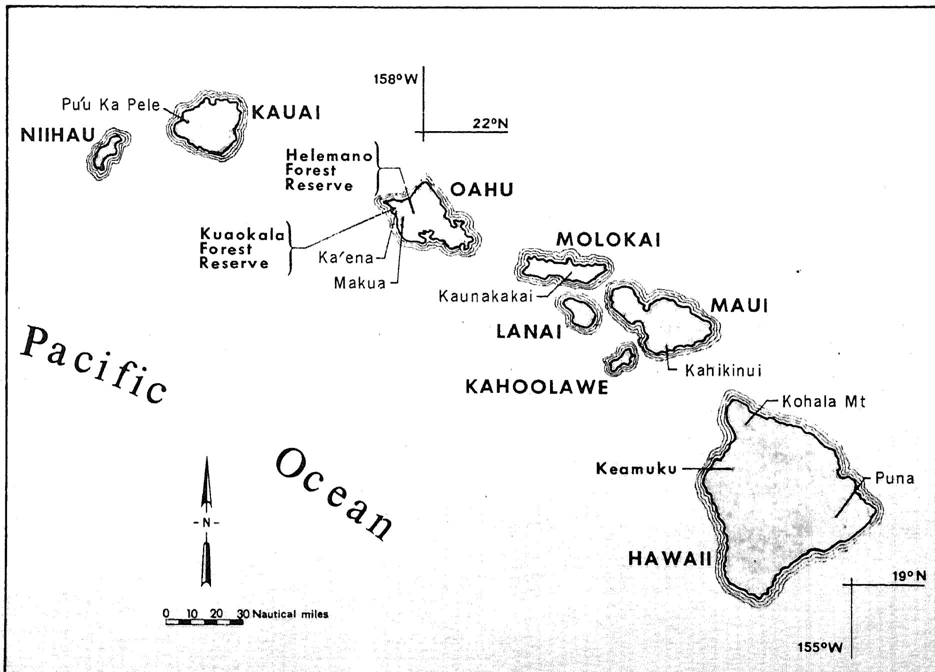


Figure 1—Broomsedge was sampled on the fringe of the Helemano (Poamoho) Forest Reserve, Oahu; molasses grass in the Kuaokala Forest Reserve near Ka'ena, Oahu; and fountaingrass in the Keamuku area of South Kohala, island of Hawaii.

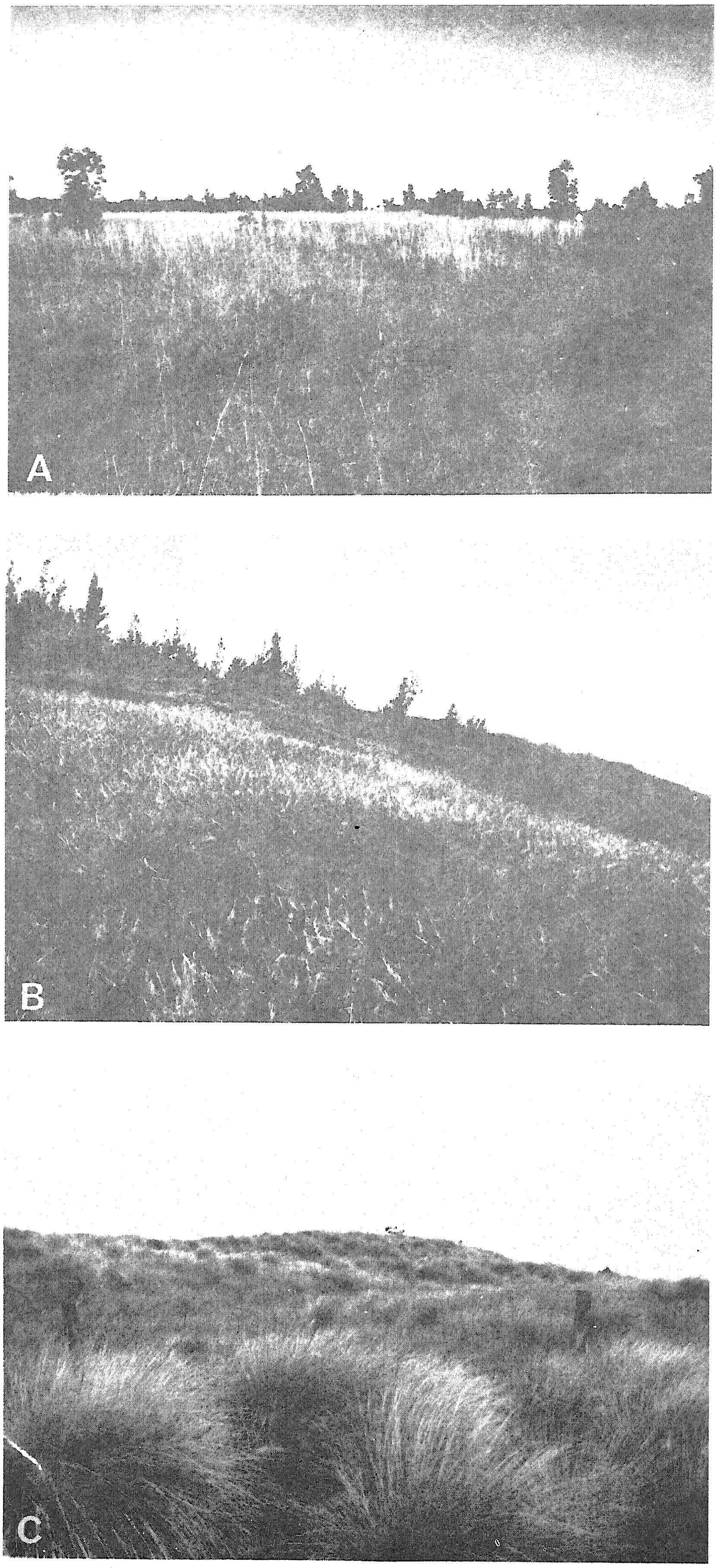
(*Andropogon virginicus*), molasses grass (*Melinis minutiflora*), and fountaingrass (*Pennisetum setaceum*).

This note reports estimates of loading, surface area-to-volume ratio, and bed depth of the three grasses studied. The results suggest that standard fuel model parameters generally underestimate the characteristics of Hawaii fine fuels.

STUDY SITES

We sampled broomsedge on the fringe of the Helemano (Poamoho) Forest Reserve, molasses grass in the Kuaokala Forest Reserve near Ka'ena, and fountaingrass in the Keamuku area of South Kohala. These fire-prone areas offered pure stands of the respective fuel types (*fig. 1*).

The broomsedge site at Helemano is on a modest slope (locally flat) west of the Koolau Range, at 427 m elevation. Median annual rainfall at the Helemano Forest Reserve for 40 years before 1958 was 207 cm.[3] In 1975, annual rainfall was 149 cm.[4] The site of molasses grass sampling is leeward of the Waianae Range ridgeline, and considerably drier. At the Kuaokala Forest Reserve, the rain gage nearest the sampled plots recorded a median annual rainfall of 81 cm in a 28-year period. In 1975, it recorded 75 cm. Molasses grass was sampled at 442-m elevation. Fountaingrass was sampled in the area where the State experiences its largest wildfires (*fig. 2*). In winter 1978, a fire swept through 12,000 acres (4856 ha) of Keamuku in 2½ days. Prolonged dry spells and strong, persistent winds can result in extremely dangerous fire conditions in the fountaingrass stands that blanket the vast lava fields, sloping gently upward from the Kona coast. Annual rainfall in the Keamuku area was 67 cm in 1975, compared to the median for 56 years of 71 cm. Site elevation is about 762 m.



re 2—Three major fine fuels studied *(A)* broomsedge, sampled at Hele-ɔ, Oahu; *(B)* molasses grass, sampled ‹a'ena, Oahu; and *(C)* fountaingrass, ɔled at Keamuku, island of Hawaii.

EXPERIMENTAL DESIGN

The sampling design was largely that of Brown,[5] and Burgan.[6] We sampled in the fuel bed at 10 points spaced 50 feet (15.24 m) apart, on a randomly placed linear transect. Four subplots were established at each point (*fig. 3*). Each subplot measured 40 × 80 cm, and was oriented parallel to the transect. By using this design, a total of 40 subplots per transect were sampled.

Within each subplot, we measured depths of leaves and stalks from each of three points at 20-cm intervals along the midlength of the subplot. Depth corresponded to the highest fuel particle intersecting an imaginary 4-inch (10-cm) diameter cylinder centered on the depth sampling point. Anderson[7] suggests that this depth be multiplied by 0.7 to obtain the best estimate of depth that influences fire behavior. We singled out the subplot with the greatest volume of plant material—the base subplot—and estimated the volume of material in the other subplots, relative to the base subplot. Because we depended on observer skill, we decided to calibrate observer judgment in field training. The volume estimates in this report, therefore, are the average of two independent observations, which generally agreed within 10 percent of each other.

To estimate fuel loading, we needed to remove the material from the subplot. We did this only on the base subplot. A portable frame about 5 feet (1.52 m) tall, constructed to the length and width of the subplot, was used to define the subplot volume. Stalks and leaves protruding from the frame were trimmed back to the face. After the volume was so defined, the material was clipped as near the ground as possible and sealed in plastic bags. The samples were air-dried and weighed.

Additionally, observers estimated the proportion of live (green) material in the base plot. Again, some field training was required to ensure reliability of observer judgment. It was generally more difficult to estimate this proportion than to estimate relative volume with respect to the base plot. We obtained an objective proportion-by-weight by separately weighing green and dead material in broomsedge and fountaingrass.

To estimate the surface area-to-volume ratios (σ), the simplest assumptions were made about stalk and leaf shapes. We assume that stalks are right cylindrical. If we denote surface area by S and volume by V, and assume that the end areas of the cylinder are negligible, then

$$\sigma = \frac{S}{V} = \frac{2\pi r l}{\pi r^2 l} = \frac{2}{r} = \frac{4}{d} \qquad \text{Eq. 1}$$

in which

r = radius of cylinder
l = length of cylinder
d = diameter of cylinder

For a simple leaf, let t be leaf thickness. Ignoring the area on the edge,

$$\sigma = \frac{S}{V} = S / \frac{St}{2} = \frac{2}{t} \qquad \text{Eq. 2}$$

Brown[8] discusses calculating surface area-to-volume ratios by using photomicrography. Estimates are obtained from Equations 1 and 2, with the arithmetic mean of stalk diameters substituted for d and the arithmetic mean of leaf thicknesses substituted for t. We choose to use the *harmonic* mean instead, for these reasons:

Assume that the arithmetic mean is the "best" estimator of some quantity.[9] Suppose we have n independent leaf thickness measurements $(x_1, x_2, \ldots x_n)$. When we compute the arithmetic mean of thickness

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i$$

$\bar{x}$ is the best estimate of leaf thickness we obtain from our sample.

We want the best estimate of surface area-to-volume ratio, however. The assumptions of the preceding paragraph lead to the conclusion that surface area-to-volume ratio is a function of the inverse of thickness. Our same sample of n leaf thicknesses can then be considered a sample of n independent surface area-to-volume ratios $(2/x_1,\ 2/x_2,\ \ldots\ 2/x_n)$. It follows that the best estimate of

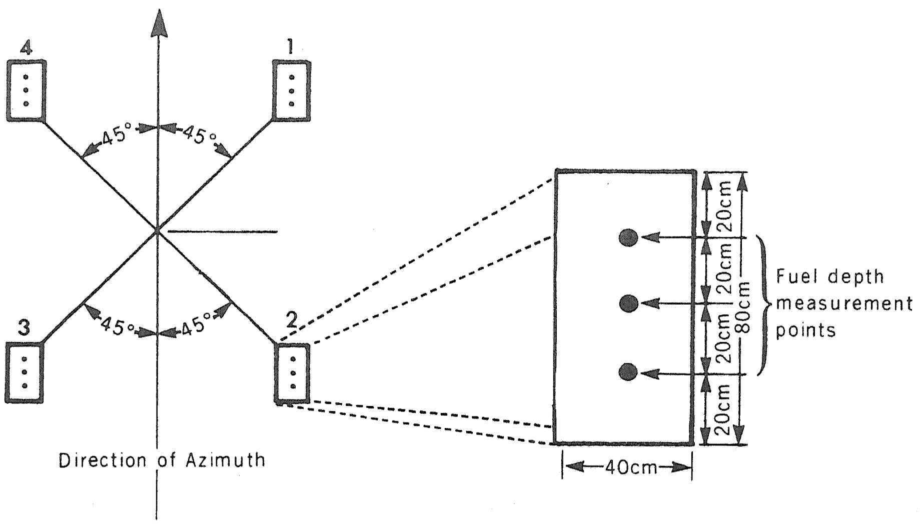


Figure 3—Sampling was done in the fuel bed at 10 points spaced 50 ft (15.24 m) apart, on a randomly placed linear transect. Four subplots were established at each point.

surface area-to-volume ratio is the arithmetic mean of the $\{2/x_i\}$:

$$\bar{\sigma}_{\text{leaf}} = \frac{2}{n}\sum_{i=1}^{n}\frac{1}{x_i}$$

The same logic applies to the best estimate of surface area-to-volume ratio for stalks, with the more general result

$$\bar{\sigma} = \frac{c}{n}\sum_{i=1}^{n}\frac{1}{x_i} \qquad \text{Eq. 3}$$

in which c is 2 for leaves and 4 for stalks. The summation is the reciprocal of the *harmonic mean*, H, of thickness (diameter) measurements. Denote the arithmetic mean of thickness (diameter) by A; it can be shown by the Cauchy-Schwartz Inequality for Sums[10] that for finite $x_i > 0$, $1/H \geq 1/A$; equality obtains when the $\{x_i\}$ are all equal. By using the arithmetic mean of thickness measurements in Equations 1 and 2, therefore, we *underestimate* σ. We should, instead, use the *reciprocal harmonic mean*, as in Equation 3.

We randomly measured leaf thicknesses and stalk diameters on the air-dried samples collected from the base subplots. Samples were scattered evenly on a table. By using the table edges as coordinate axes, and a table of random numbers, we generated bivariate random coordinates, at which we located a leaf or stalk sample. A vernier caliper with 0.001-inch graduations measured thickness and diameter. Twenty measurements were obtained for each subplot on even-numbered points in the transect. The surface area-to-volume ratio was estimated on the basis of a sample size of 100.

DISCUSSION

The stalk cross-sections, particularly in fountaingrass, were sometimes more elliptic than circular. We attempted, therefore, to measure the major and minor axes of the ellipse on fountaingrass stalks. We did the same on molasses grass stalks, although they were less elliptic than the fountaingrass stalks.

By assuming a right elliptic cylindrical fuel, the surface area-to-volume calculation is encumbered by an elliptic integral, namely, a complete elliptic integral of the second kind, which determines the perimeter of the fuel cross-section normal to the length. We use an approximation of the elliptic integral,[11] and obtain

$$\sigma = \frac{S}{V} = \frac{2\pi\{\frac{1}{2}[(\frac{c}{2})^2 + (\frac{d}{2})^2]\}^{1/2}\, l}{\pi(\frac{c}{2})(\frac{d}{2})\, l}$$

$$= \frac{4[\frac{1}{2}(c^2+d^2)]^{1/2}}{cd} \qquad \text{Eq. 4}$$

in which

c = major axis
d = minor axis

When c = d, Equation 4 becomes identical to Equation 1. By definition of eccentricity, ϵ, of an ellipse,

$$\epsilon = \frac{(c^2-d^2)^{1/2}}{c}$$

we can express Equation 4 as

$$\sigma = \frac{4\{\frac{1}{2}[c^2+c^2(1-\epsilon^2)]\}^{1/2}}{c[c^2(1-\epsilon^2)]^{1/2}}$$

$$= \frac{4}{c}\left(\frac{1-\epsilon^2/2}{1-\epsilon^2}\right)$$

The approximation to the elliptic integral,

$$2c\int_0^{\pi/2}(1-\epsilon^2\sin^2\phi)^{1/2}\,d\phi$$

$$\doteq \pi[\frac{1}{2}(c^2+d^2)]^{1/2}$$

which first appears in Equation 4, is good, even for high eccentricity. With $\epsilon = 0.7071$, for example, the error of the approximation is 0.0072 (on the basis of 5 significant digits).

The statistics for stalk and leaf surface area-to-volume ratios were computed from the inverse of thickness measurements. They were generated by BMDP Program 2D,[12] which computes descriptive statistics for a

Table 1—*Minimum and maximum, mean, median, variance, and standard error of the mean for stalk and leaf depths of three major grass fuels in Hawaii*

Species	Min	Max	Mean	Median	Variance	Standard error of the mean
			Inches (cm)			
Andropogon virginicus						
(Broomsedge)						
Stalk	0 (0)	41 (104)	26.86 (68.22)	31.0 (78.7)	107.33 (692.45)	0.95 (2.41)
Leaf	3 (8)	28 (71)	15.74 (39.98)	16.0 (40.6)	19.03 (122.77)	0.40 (1.02)
Melinis minutiflora						
(Molasses grass)						
Stalk	0 (0)	47 (119)	26.32 (66.85)	27.0 (68.6)	109.07 (703.68)	0.95 (2.41)
Leaf	0 (0)	46 (117)	26.88 (68.28)	28.0 (71.1)	99.16 (639.74)	0.91 (2.31)
Pennisetum setaceum						
(Fountaingrass)						
Stalk	0 (0)	62 (157)	31.38 (79.71)	34.5 (87.6)	293.11 (1891.03)	1.56 (3.96)
Leaf	0 (0)	49 (124)	36.28 (92.15)	39.0 (99.1)	94.89 (612.19)	0.90 (2.29)

Table 2—*Minimum and maximum, mean, median, variance, and standard error of the mean for stalk and leaf surface area-to-volume ratios of three major grass fuels in Hawaii*

Species	Min	Max	Mean	Median	Variance	Standard error of the mean
	1/ft (1/cm)					
Andropogon virginicus (Broomsedge)						
Stalk	533 (17)	6000 (197)	1064 (35)	906 (30)	541,661 (583)	74 (2.4)
Leaf	4000 (131)	12000 (394)	7036 (231)	6000 (197)	3,575,256 (3848)	189 (6.2)
Melinis minutiflora (Molasses grass)						
Stalk	471 (15)	1200 (39)	676 (22)	658 (22)	16,714 (18)	13 (0.4)
Leaf	3000 (98)	8000 (262)	4536 (149)	4400 (144)	972,947 (1047)	99 (3.2)
Pennisetum setaceum (Fountaingrass)						
Stalk	326 (11)	962 (32)	590 (19)	583 (19)	15,677 (17)	13 (0.4)
Leaf	2182 (72)	6000 (197)	3447 (113)	3429 (112)	534,373 (575)	73 (2.4)

Table 3—*Weighting factors for leaf and stalk, and for live and dead categories, by species*

Species	Weighting factors			
	Leaf	Stalk	Live	Dead
Andropogon virginicus	0.6634	0.3366	0.4463	0.5537
Melinis minutiflora	0.3465	0.6535	0.3252	0.6748
Pennisetum setaceum	0.4168	0.5832	0.3405	0.6595

Table 4—*Bed depth and surface area-to-volume ratios, by species*

Species	Bed depth	Surface area-to-volume ratio
	Feet (m)	*1/ft (1/cm)*
Andropogon virginicus	1.624 (0.495)	5026 (165)
Melinis minutiflora	2.210 (0.674)	2013 (66)
Pennisetum setaceum	2.785 (0.849)	1781 (58)

Table 5—*Minimum and maximum, mean, median, variance, and standard error of the mean fuel weight on base subplots, and the corresponding loading, by species*

Species	Min	Max	Mean	Median	Variance	Standard error of the mean	Loading
	Lb (kg)						*Lb/ft² (kg/m²)*
Andropogon virginicus	0.300 (0.136)	0.723 (0.328)	0.427 (0.194)	0.404 (0.183)	0.0169 (0.0035)	0.041 (0.019)	0.124 (0.605)
Melinis minutiflora	1.138 (0.516)	4.159 (1.887)	2.332 (1.058)	2.119 (0.961)	0.9987 (0.2055)	0.316 (0.143)	0.677 (3.305)
Pennisetum setaceum	0.514 (0.233)	2.344 (1.063)	1.376 (0.624)	1.312 (0.595)	0.3198 (0.0658)	0.179 (0.081)	0.400 (1.953)

univariate distribution. The means correspond to Equation 3. The medians also are estimated with respect to the $\{c/x_i\}$.

The refinements to surface area-to-volume that we estimated required more effort than was originally planned. In view of the nonlinear dependence of Rothermel's rate of spread model on σ,[13] however, the additional work is justified.

RESULTS

We found pronounced differences in the fuel characteristics of leaves and stalks, particularly for surface area-to-volume ratios (*tables 1 and 2*). We weighted the mean values for leaf and stalk according to the ovendry weights of grab samples of the plant that were segregated into leaf and stalk masses, and also into live and dead masses (*table 3*). Estimates of bed depth and surface area-to-volume ratio in *tables 1 and 2*, weighted with the leaf and stalk proportions in *table 3*, produce the weighted means in *table 4*. On the basis of our study, they represent the estimates of bed depth and surface area-to-volume ratio that are appropriate for a fuel model of each.

Finally, we estimated fuel loading from the base subplot samples (*table*

Table 6—*Minimum and maximum, mean, median, variance, and standard error of the mean fuel weight for all subplots, and the corresponding loading, by species*

Species	Min	Max	Mean	Median	Variance	Standard error of the mean	Loading
	Lb (kg)						*Lb/ft² (kg/m²)*
Andropogon virginicus	0.143 (0.065)	0.524 (0.238)	0.273 (0.124)	0.253 (0.115)	0.0111 (0.0023)	0.033 (0.015)	0.079 (0.386)
Melinis minutiflora	0.458 (0.208)	3.481 (1.579)	1.721 (0.781)	1.786 (0.810)	0.8807 (0.1812)	0.297 (0.135)	0.500 (2.441)
Pennisetum setaceum	0.347 (0.157)	0.966 (0.438)	0.616 (0.279)	0.600 (0.272)	0.0487 (0.0100)	0.070 (0.032)	0.179 (0.874)

Table 7—*Dead and live weights and corresponding loadings, by species*

Species	Weight	Loading
	Lb (kg)	*Lb/ft² (kg/m²)*
Andropogon virginicus		
Dead	0.151 (0.068)	0.044 (0.215)
Live	0.122 (0.055)	0.035 (0.171)
Melinis minutiflora		
Dead	1.161 (0.527)	0.337 (1.645)
Live	0.560 (0.254)	0.163 (0.796)
Pennisetum setaceum		
Dead	0.406 (0.184)	0.118 (0.576)
Live	0.210 (0.095)	0.061 (0.298)

5). The sample size for each species is 10, which represents the number of base subplots per transect. The mean values in the table cannot be used without recognizing that the samples on which they are based (base subplots) had relative maximum volumes. To compensate for this bias, we use estimates of fuel volume the "nonbase" subplots had relative to the base subplots. Let w_i be the loading estimate and w_{io} the airdry weight of the base subplot material at stake i on the transect; let $\{v_{ij}\}$ be the volume proportions, relative to the base subplot, on the nonbase subplots at stake i. Then

$$w_i = (1+\sum_{j=1}^{3} V_{ij})\, w_{io}/4$$

The $\{w_i\}$, averaged in the usual manner, yield the loading statistics (*table 6*). We tried two approaches to apportioning the loadings among live and dead categories. In the first, we used observations of percent green, and in the second, we used the proportions-by-weight data for live and dead (*table 3*). The analysis of simultaneous observed estimates of percent green and proportions-by-weight indicated that the observed estimates are consistently lower than the latter, by an average of 8.9 percent. Differences between the two approaches were analyzed by using the Wilcoxon signed rank test.[14] For eight differences, we observed a Wilcoxon signed rank statistic, w = 2. The corresponding 2-tailed significance probability was 0.0234, which we consider significant. Ocular estimates of live and dead loading proportions are apparently not easy to make, without appreciable statistical error. (By error, we mean the difference between the proportions of live vegetation estimated (a) by observation, and (b) by weight measurements.)

The dead and live loadings reported were calculated using the proportions-by-weight (*table 7*).

CONCLUSIONS

Characteristics of the fuels we studied differ considerably from those of the standard fuel models. The surface area-to-volume ratio measured in broomsedge is 2.51 times as large as that in the National Fire-Danger Rating System model for perennial grass, and 1.44 times as large as the largest area-to-volume ratio of the models described by Albini.[15] Use of the *reciprocal harmonic mean* of thickness measurements to estimate σ, which we justify, gives larger values than the reciprocal arithmetic mean. The dead fuel loading we measured in molasses grass is larger than any of the other loadings for dead 1-hour fuels in the standard models. Calculations by Burgan,[16] using, Hilo, Hawaii weather data, indicate that the fuel characteristics reported in this study yield significantly higher fire danger indices than those produced by Model L of the 1978 NFDRS.[17] Further study is needed to determine the effect of the new estimates on criteria for the adjective fire danger classes. This will require a comparison of the empirical distributions of the respective fuel models.

Acknowledgments

We thank Robert E. Burgan, Intermountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture, Missoula, Mont., for his assistance throughout the study. We also thank the Hawaii Division of Forestry for help in data collection; in particular, we thank Pat Costales, Ed Petteys, and Masa Takaoka.

NOTES

1 Burgan, Robert E., Francis M. Fujioka, and George H. Hirata. 1974. *A fire-danger rating system for Hawaii.* Fire Technol. 10(4):275-281.

2 Helfman, Robert S., John E. Deeming, Robert J. Straub, and R. William Furman. 1975. *User's guide to AFFIRMS: time-share computerized processing for fire danger rating.* USDA Forest Serv. Gen. Tech. Rep. RM-15, 107 p., Rocky Mountain Forest and Range Exp. Stn., Fort Collins, Colo.

3 Taliaferro, William J. 1959. *Rainfall of the Hawaiian Islands.* 394 p. Hawaii Water Authority, Honolulu, Hawaii.

4 NOAA. 1975. *Climatological data Hawaii and Pacific annual summary.* U.S. Dep. Commerce, Natl. Oceanic Atmos. Adm., Environ. Data Serv., Asheville, N.C.

5 Personal communication from James K. Brown, Intermountain Forest and Range Exp. Stn., Missoula, Mont., June 1975.

[6] Burgan, Robert E. 1975. *Study plan—Determination of physical characteristics of selected wildland fuels in Hawaii.* Pacific Southwest Forest and Range Exp. Stn., Honolulu, Hawaii.

[7] Personal communication from Hal E. Anderson, Intermountain Forest and Range Exp. Stn., Missoula, Mont., Nov. 29, 1979.

[8] Brown, James K. 1970. *Ratios of surface area to volume for common fine fuels.* Forest Sci. 16(1):101-105.

[9] Baird, D. C. 1962. *Experimentation: an introduction to measurement theory and experiment design,* p. 133-138, Prentice-Hall, Inc., Englewood Cliffs, N.J.

[10] Spiegel, Murray R. 1968. *Mathematical handbook of formulas and tables,* p. 185, McGraw-Hill Book Co., New York, N.Y.

[11] Spiegel, Murray R. 1968. *Mathematical handbook of formulas and tables,* p. 7, McGraw-Hill Book Co., New York, N.Y.

[12] Dixon, W. J. and M. B. Brown (eds.). 1979. *BMDP-79 biomedical computer programs P-series 1979,* p. 146-154, Univ. Calif. Press, Berkeley, Calif.

[13] Rothermel, Richard C. 1972. *A mathematical model for predicting fire spread in wildland fuels.* USDA Forest Serv. Res. Paper INT-115, 40 p., Intermountain Forest and Range Exp. Stn., Ogden, Utah.

[14] Lehmann, E. L. 1975. *Nonparametrics: statistical methods based on ranks,* p. 123-132, Holden-Day, Inc., San Francisco, Calif.

[15] Albini, Frank A. 1976. *Computer-based models of wildland fire behavior: a user's manual,* p. 21, Intermountain Forest and Range Exp. Stn., Ogden, Utah.

[16] Personal communication from Robert E. Burgan, Intermountain Forest and Range Exp. Stn., Missoula, Mont., Oct. 1979.

[17] Deeming, John E., Robert E. Burgan, and Jack D. Cohen. 1977. *The National Fire-Danger Rating System—1978.* USDA Forest Serv. Gen. Tech. Rep. INT-39, 63 p., Intermountain Forest and Range Exp. Stn., Ogden, Utah.

The Authors

FRANCIS M. FUJIOKA is a research meteorologist assigned to the Station's forest and brushland meteorology research unit, Riverside, California. He was formerly with the Hawaiian forest ecosystems unit in Honolulu. He earned a B.S. degree (1968) and an M.S. degree (1972) in meteorology at the University of Hawaii, and an M.A. degree (1979) in statistics at the University of California, Berkeley. He joined the Forest Service and the Station staff in 1972.

DAVID M. FUJII is a forester assigned to the timber and watershed management research unit, with headquarters in Honolulu, Hawaii. He earned an A.S. degree (1967) in forestry at Boise State College, Idaho, and a B.S. degree (1972) in forest resource management at the University of Idaho. He joined the Forest Service and the Station staff in 1974.

The Forest Service of the U.S. Department of Agriculture

...Conducts forest and range research at more than 75 locations from Puerto Rico to Alaska and Hawaii.

...Participates with all State forestry agencies in cooperative programs to protect and improve the Nation's 395 million acres of State, local, and private forest lands.

...Manages and protects the 187-million-acre National Forest System for sustained yield of its many products and services.

The Pacific Southwest Forest and Range Experiment Station

...Represents the research branch of the Forest Service in California, Hawaii, and the western Pacific.